

## METHOD FOR CONTROLLING A TRANSMISSION

### EXPRESS MAIL CERTIFICATE

Date 7/9/03 Label No. SV340065161-05

I hereby certify that, on the date indicated above, this paper or fee was deposited with the U.S. Postal Service & that it was addressed for delivery to the Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450 by "Express Mail Post Office to Addressee" service.

D B Peck

Name (Print)

[Signature]

Signature

5

### CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation of International Patent Application Serial No. PCT/DE01/04779 filed December 17, 2001, which is hereby incorporated by reference in its entirety.

10

### BACKGROUND OF THE INVENTION

The present invention relates to a method for the control and/or regulation of an automated clutch and/or an automated transmission of a vehicle, wherein a target value for the clutch torque is determined by means of an electronic clutch management system (ECM). The invention further relates to a control- and/or regulation device, as well as an automated transmission.

15

20

Automated clutches and/or automated transmissions are known from the field of automotive technology as a means by which a complete automation of the drive train of a vehicle, in particular a motor vehicle, is made possible. A clutch-  
5 engaging process during a desired gear-shifting process is automated by means of an electronic clutch management system (ECM) .

To achieve this purpose, it is necessary that an  
10 appropriate target amount for the clutch torque at the current operating conditions is determined with the aid of the automated clutch. In particular during the start-up phase of a motor vehicle, more demanding requirements are placed on the clutch management system. For example, possibilities for  
15 driver input must be taken into consideration to a certain extent, and changed operating conditions, e.g. an increase in engine torque in turbo engines, or properties of the clutch, must also be taken into account.

20

#### OBJECT AND SUMMARY OF THE INVENTION

The object of the invention is to provide a method for the control and/or regulation of an automated clutch and/or an

automated transmission with an improved functionality of the electronic clutch management in particular during the start-up phase.

5           To meet the foregoing objective, the invention provides a method wherein the electronic clutch management determines a start-up function that depends on predetermined input parameters and delivers the target value for the clutch torque as an output parameter which is then set at the clutch of the  
10 vehicle. As a consequence, the start-up rpm-rate in a motor vehicle with automated clutch control and/or transmission control can to a greater extent conform to the desire of the driver as it manifests itself, e.g., through a position of the accelerator pedal or the throttle valve. The functionality of  
15 the electronic clutch management in the start-up phase is expanded so that in particular a defined engine rpm-rate can be set during the start-up phase. This provides the possibility of an improved reproducibility of vehicle starts from a standstill under variable operating conditions.

20

According to an advantageous development of the invention, the target value for the clutch torque can be determined by means of the start-up function dependent on input parameters that include at least one of the following:

accelerator pedal angle, engine rpm-rate, transmission input rpm-rate and/or engine torque.

Under a proposed concept of the invention, the start-up function is essentially divided into two phases with the aid of a factor calculation. Of course, it is also possible to provide additional phases in order to further optimize the start-up process in a vehicle.

According to an advantageous concept of the inventive method, the factor calculation in a first phase of the regulation preferably ensures that the engine rpm-rate essentially follows a targeted start-up rpm-rate. In a second phase, in contrast, a matching of the engine rpm-rate and the transmission input rpm-rate is required in order to synchronize the two rpm-rates. This avoids a sharp switch-over between the phases, and a continuous change-over of the two phases is made possible within the start-up process as a function of a so-called rpm-ratio, which is defined as the quotient between transmission input rpm-rate and engine rpm-rate.

An advantageous embodiment of the invention provides that to calculate the target value for the clutch torque as the output quantity, the first step is to determine a torque

contribution in accordance with a global control function.

This can be accomplished, e.g., by determining contributing factors as functions of the transmission input rpm-rate and/or

the engine rpm-rate. Moreover it is also possible to use an

5 engine-torque-dependent contribution. It is particularly

advantageous, however, if the engine-torque-dependent portion

is suitably weighted by means of the rpm-ratio so that the

engine-torque-dependent portion achieves its full effectiveness

at the clutch just as the point of synchronization is reached.

10 Of course, it is also conceivable to use additional

contributing factors in determining the start-up function.

It has been found that a suitable gradient limitation for example of the engine-torque-dependent portion is

15 particularly advantageous in order to further improve the

start-up functionality of the electronic clutch management by

means of the method according to the invention.

The above-mentioned portions or contributions can be

20 supplemented e.g. by appropriate contributing parts of the

regulation that have the purpose of ensuring the above-

mentioned phase-specific tasks.

According to another development of the invention, for example at lower values of the rpm-ratio, for example if the value of the rpm-ratio (SR) is less than about 0.5 to 0.7, an initial regulation of the targeted start-up rpm-rate may be of primary concern. It is possible for the start-up rpm-rate to be determined through a suitable, e.g., monotonically increasing characteristic curve as a function of the accelerator pedal angle. Of course, it is also possible to use any other, differently defined characteristic curve, if desired.

To avoid that rapid and/or occasionally opposite changes of the accelerator pedal angle or of the throttle valve angle produce changes in the target value for the clutch torque, the determined starting rpm-rate is for example low-pass-filtered, preferably with a PT1 element. It is also conceivable that other filter elements can be used.

According to an advantageous development, the filter function is initialized by means of the engine rpm-rate, in particular when the engine rpm-rate in neutral gear considerably exceeds an idle rpm-rate of, e.g., about 500 rpm. Of course, the initialization can also take place at lower or higher values.

The difference  $f_1(SR) \cdot (n_{start} - n_{eng})$  weighted by the rpm-ratio in the factor calculation can be converted e.g. via a PI (proportional / integrating) controller into a contribution to the target value for the clutch torque. The PI controller can have as parameters the factor KP1 of the proportional term and the factor KI1 of the integrating term. Of course, another controller and/or other parameters can also be used.

10

In particular for higher values of the rpm-ratio, e.g., if the value of the rpm-ratio (SR) is larger than 0.6 to 0.9, the attainment of the synchronous point can become the primary concern in the factor calculation. It is conceivable that the attainment of the synchronous point can also receive primary attention at rpm-ratios that differ from the aforementioned values.

15

According to a further developed version of the invention, a PI controller can also be used whose input quantity represents, e.g.,  $f_2(SR) \cdot (n_{eng} - n_{trsm})$ . Preferably the PI controller uses as parameters the factor KP2 of the proportional term and the factor KI2 of the integrating term.

20

Here too, the use of other controllers and/or parameters is possible.

A further development of the invention provides that  
5 the I-terms of the two regulations are preferably implemented  
by the same integrator. This advantageously reduces the  
complexity of the circuit that is used in the implementation of  
the regulation. In addition to the existing integrator, it is  
also possible to use an additional integrator, for example in a  
10 serial arrangement. The additional integrator can for example  
have a smaller amplification  $KI_3$ , in order to counteract  
continuous slip of the clutch, for example due to ramp-shaped  
disturbance variables such as a continuously increasing engine  
torque. It is conceivable to use additional integrators, also  
15 in a different circuit configuration, as well as larger or  
smaller amplification factors.

According to another development of the inventive  
method, the target value for the clutch torque determined as  
20 the output quantity is subject to a limitation. For example,  
the target value for the clutch torque ( $M_{Rtrgt}$ ) can be limited  
by the condition  $M_{Rtrgt} = 0$ . If the target value for the  
clutch torque is subject to such a limitation, the one or more  
integrators used in the control system can be subject to a



suitable measure to avoid a so-called wind-up. This can be achieved, e.g., by calculating backwards to a corresponding I-portion ( $M_I$ ) of the torque after setting a limit for the target value for the clutch torque. This can preferably be  
5 done by subtracting the torque contribution of the global control ( $M_{glob}$ ) and a damping torque portion ( $M_D$ ), as well as by adding the proportional portions  $M_{P1}$  and  $M_{P2}$  of the PI-controller of the first and second phase in the factor calculation, from or to the limited target value for the clutch  
10 torque ( $M_{Rtrgt\_lim}$ ).

This can be expressed through the following equation:

$$M_I = M_{Rtrgt\_lim} - M_{glob} - M_D + M_{P1} + M_{P2}$$

15 wherein

$M_{Rtrgt\_lim}$  = limited target value for the clutch torque

$M_D$  = damping torque portion

$M_{P1}$  = P-portion of the torque in the first phase

$M_{P2}$  = P-portion of the torque in the second phase

20

Of course, other or additional portions can also be taken into consideration in backwards-calculating to the I-portion of the torque.

According to a further variant of the inventive method,  
a damping portion can enter into the determination of the  
start-up function. This damping portion can be processed both  
in the first phase, i.e., during the initiation of the  
5 regulation of the starting rpm-rate, and in the second phase of  
the factor calculation, i.e., during synchronizing or slip  
reduction. In the first phase, the use of the damping portion  
can advantageously prevent a sharp change, e.g., in the engine  
rpm-rate. In the second phase or synchronizing phase, the  
10 damping portion is preferably applied to the difference between  
engine rpm-rate and transmission input rpm-rate.

According to another development of the invention, in  
determining the target value for the clutch torque by means of  
15 the start-up function, e.g., the transmission input rpm-rate-  
and/or engine-rpm-rate-dependent portion is omitted. Of  
course, any other desired portions can be reduced or omitted in  
order to further optimize the overall determination of the  
start-up function in the inventive method.

20

In a further variation of the invention it is  
advantageous if, e.g., a throttle-valve-dependent portion  $K(\alpha)$   
is used in determining the start-up function. By introducing

the portion  $K(\alpha)$ , one obtains the following equation for  $M\_Rtrgt$ :

$$M\_Rtrgt = K(\alpha) * f(n\_eng)$$

5

wherein  $f(n\_eng)$  stands for a function that depends on the engine rpm-rate.

According to the invention, this throttle-valve-  
10 dependent portion can be used either alone or in combination with the already named portions for determining the start-up function. By using the throttle-valve-dependent portion, the target value for the clutch torque can be reduced, e.g., when the throttle valve angle increases, in order to raise the  
15 starting rpm-rate and to prevent a condition where the engine rpm-rates stay practically the same over large range of torque loads during the start-up process. In particular the throttle-valve-dependent term and/or the engine-rpm-rate-dependent term can be reduced in the calculation of the target value for the  
20 clutch torque.

Taking the stationary and dynamic processes into consideration during a start-up process of a motor vehicle, a further embodiment of the invention includes the provision that

at least the gradient of a portion is suitably limited in the determination of the start-up function. Limiting the gradient of the throttle-valve-dependent term and/or the engine-rpm-rate-dependent term is particularly advantageous. By a

5 suitable selection of the limits, in particular in the gradient of the throttle-valve-dependent term, the influence of the the throttle-valve-dependent term can be reduced to such an extent that undesired acceleration of the vehicle can be avoided.

10 In particular the dynamic processes during a start-up phase are represented by the following equation

$$\frac{d}{dt}M_{Rtgt} = f(n_{eng}) * \frac{dK(\alpha)}{d\alpha} * \frac{d\alpha}{dt} + K(\alpha) * \frac{df(n_{eng})}{dn_{eng}} * \frac{dn_{eng}}{dt}$$

15 wherein  $n_{eng}$  represents the engine rpm-rate and  $K(\alpha)$  represents the throttle-valve-dependent term.

During a load change, in particular a so-called tip-in (abrupt depression of the gas pedal), a breakdown of the target  
20 value for the clutch torque subsequent to the tip-in can largely be avoided by means of a suitable limitation of the gradient of the throttle-valve-dependent term. Depending on the operating conditions, a suitable limitation of the gradient

must be found in order to ensure an optimized starting process overall.

A limitation of the amount of the gradient is also  
5 advantageous during another type of engine-load change, in particular a back-out (sudden let-up on the gas pedal). An undesired closing of the clutch during the back-out can be completely suppressed by means of an extremely flat increase of the throttle-valve-dependent term.

10

The inventive method as described herein can in principle be used in an electronic clutch management system (ECM) and also in an automated shift transmission (AST). Moreover it is also conceivable that the method according to  
15 the invention can be used in a continuously variable transmission (CVT).

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

20

Advantageous embodiments of the invention are revealed in the drawings and their description, wherein:

Figure 1 represents a block diagram of the method according to the invention;

Figure 2 shows a time graph of a typical start-up process;

Figure 3 shows a time graph of a start-up process with a tip-in; and

Figure 4 shows a time graph of a start-up process with a back-out.

#### DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Figure 1 illustrates a start-up strategy in the form of a block diagram. The illustrated strategy, in which the start-up rpm-rate is regulated, is in particular compatible with a global control concept.

In the start-up strategy of Figure 1, the accelerator pedal angle  $PWG$ , the engine rpm-rate  $n_{eng}$ , the transmission input rpm-rate  $n_{trsm}$ , and the engine torque  $Me$  represent the input quantities. These input quantities are processed to produce the target value for the clutch torque  $M_{Rtrgt}$  which represents the output quantity.

Based on the accelerator pedal angle, a start-up rpm-rate is determined through a calculation of a target value for the start-up rpm-rate. The start-up rpm-rate is aligned with the engine rpm-rate and serves as an input quantity for the first phase (regulation of the start-up rpm-rate). This input parameter is converted into torque contributions  $M_{P1}$  and  $M_I$  by way of a PI controller with the parameters  $K_{P1}$  and  $K_{I1}$ .

The engine rpm-rate is brought in line with the transmission input rpm-rate and serves as an input quantity for the synchronizing phase. The synchronization block of Figure 1 also contains a PI controller with the parameters  $K_{I2}$  and  $K_{Pp2}$ , so that a torque contribution  $M_{P2}$  is delivered at the output. The I-portion of the PI controller is added to the I-portion of the PI controller assigned to the block representing the regulation of the starting rpm-rate and fed to an integrator. The output quantity of the integrator represents the torque portion  $M_I$ .

The engine rpm-rate and the transmission input rpm-rate serve as input quantities for the factor calculation, in which an rpm-ratio  $SR$  defined by the quotient  $SR$  of transmission input rpm-rate and engine rpm-rate represents a weight factor. The weighting is carried out by the functions  $f_1(SR)$  and  $f_2(SR)$ .

The function  $f_1$  (SR) serves as an input quantity for the block representing the regulation of the start-up rpm-rate and the function  $f_2$  (SR) serves as an input quantity for the block representing the rpm-synchronization.

5

The engine rpm-rate is also used as an input quantity for the damping portion. In the damping portion, the function  $f_1$ (SR) exerts an additional influence, so that a damping torque contribution  $M_D$  is delivered at the output of the block that  
10 represents the damping portion.

The engine torque is weighted by means of the factor calculation and forms an input quantity for the global control. The engine rpm-rate and the transmission input rpm-rate are  
15 also provided as input quantities for the global control. A torque contribution  $M_{glob}$  is output as a combined output quantity.

The damping torque contribution  $M_D$  is superimposed on  
20 the combined output quantities of the blocks representing the regulation of the start-up rpm-rate and the synchronization. The output quantity formed thereby is then added to the torque contribution  $M_{glob}$  and as a final result represents the



desired target value for the clutch torque  $M_{Rtrgt}$  as an output quantity.

Figure 2 shows a starting process in the form of a time graph. The diagram is divided into the first phase (regulation of the start-up rpm-rate) and the second phase (synchronization or slip reduction). The time profiles of the start-up rpm-rate  $n_{start}$ , the engine rpm-rate  $n_{eng}$ , and the transmission input rpm-rate  $n_{trsm}$  are shown in the diagram.

It is clear that in the first phase the engine rpm-rate is adjusted to the start-up rpm-rate so that at the end of the first phase the two rpm-rates are equal. At the beginning of the second phase (synchronizing phase), the engine rpm-rate is adjusted to the transmission input rpm-rate and thus leaves the time graph of the starting rpm-rate.

After about 3 seconds, the engine rpm-rate and transmission input rpm-rate are approximately identical, so that the further time profiles of the engine rpm-rate and the transmission input rpm-rate are identical. From this point on, the engine rpm-rate and the transmission input rpm-rate are synchronized.

Figure 3 shows a start-up process with a so-called tip-in. The diagram includes two curves, wherein the target value for the clutch torque  $M_{Rtrgt}$  and the engine rpm-rate  $n_{eng}$  as functions of time are shown as broken lines, the transmission input rpm-rate  $n_{trsm}$  as a dash-dotted line, and both a throttle-valve-dependent factor  $K(\alpha)$  and the throttle valve angle TVA as solid lines.

The effect of the gradient limitation of  $K(\alpha)$  in a start-up process with tip-in is clear from the diagram. The limited gradient of  $K(\alpha)$  can be seen in the upper illustration. Due to this limitation, a breakdown of the target value for the clutch torque  $M_{Rtrgt}$  subsequent to the tip-in can largely be avoided. It must be noted, however, that a compromise must be made in matching the gradient.

Figure 4 shows a starting process with back-out. The diagram includes two graphs, wherein the target value for the clutch torque  $M_{Rtrgt}$  and the engine rpm-rate  $n_{eng}$  as functions of time are shown as broken lines, the transmission input rpm-rate  $n_{trsm}$  as a dash-dotted line, and both a throttle-valve-dependent factor  $K(\alpha)$  and the throttle valve angle TVA as solid lines.

The effect of the gradient limitation of  $K(\alpha)$  in a starting process with back-out is clear from the diagram. The limited gradient of  $K(\alpha)$  can be seen in the upper illustration.

5 A sudden closing of the clutch prior to the synchronization of  $n_{eng}$  and  $n_{trsm}$  can be completely suppressed by means of an extremely flat increase of  $K(\alpha)$ .

A gradient limitation on one or more portions is  
10 advantageous for the determination of the target value for the clutch torque, so that in particular the start-up functionality of an automated clutch and/or an automated transmission is improved.

15 Without further analysis, the foregoing will so fully reveal the essence of the present invention that others can, by applying current knowledge, readily adapt it for various applications without omitting essential generic or specific features that set the present invention apart from the prior  
20 state of the art. Therefore, such adaptations should be understood to fall within the scope and range of equivalence of the appended claims.